DAAD17-01-C-0073

ARMY RESEARCH LABORATORY

THE JIGSAW PROJECT

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Volumetric Compression/Restoration For LADAR Imagery

A Final Report on the Arizona JIGSAW Project

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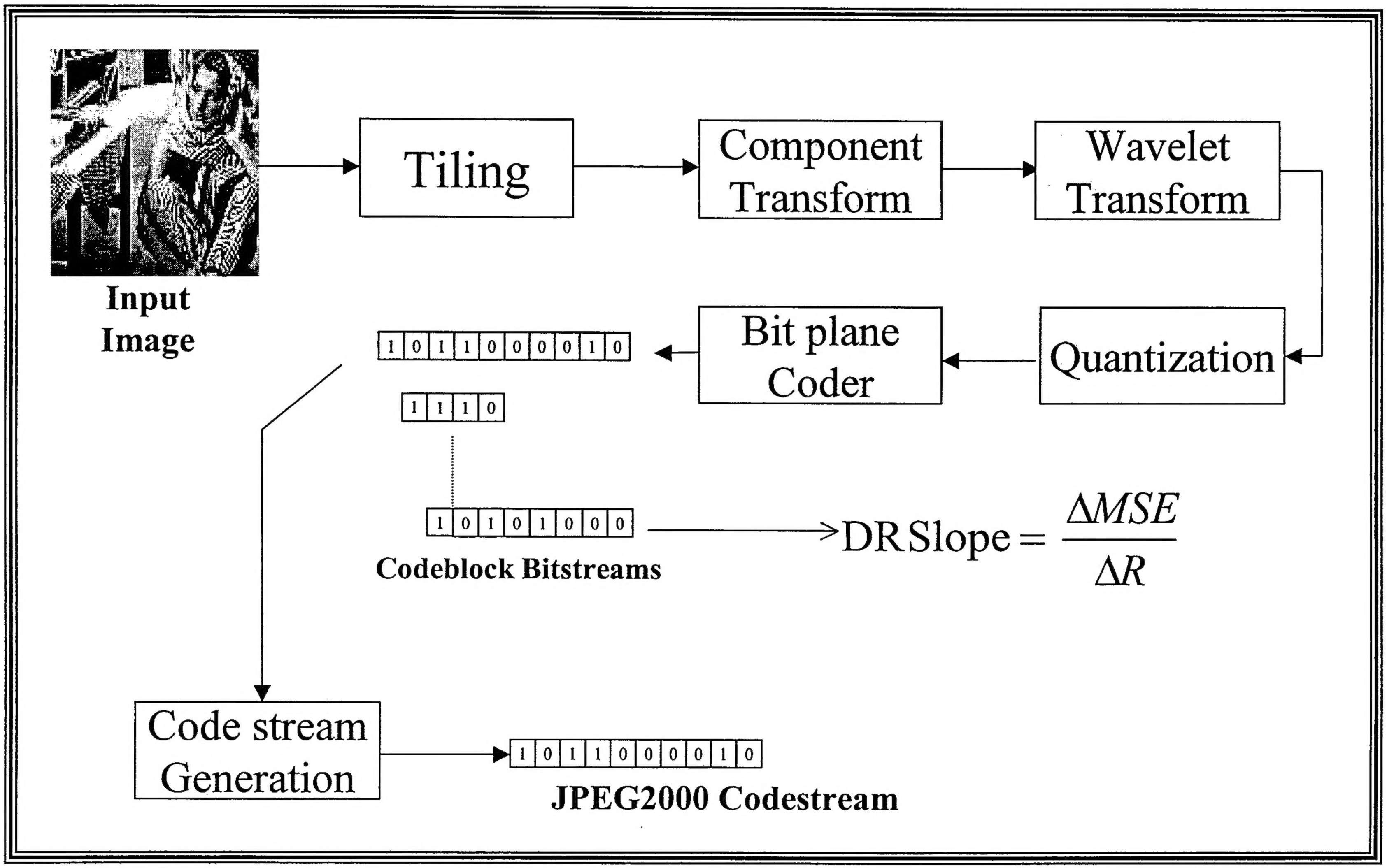
Outline

- Sensor Geometry/Physical Setup.
- Overview of the Compression Engine: JPEG2000
- Compression of 2D Range Imagery
  - Independent, Frame-by-Frame:
  - Interdependent Frames:
    - ✓ MC vs. 3DWT
- Volumetric Image Compression
  - 3D Histograms vs Binary Volumes.
  - Choice of a Performance Metric.
  - Accumulated Volumes
    - ✓ Lossy and Lossless Compression.
- Conclusions

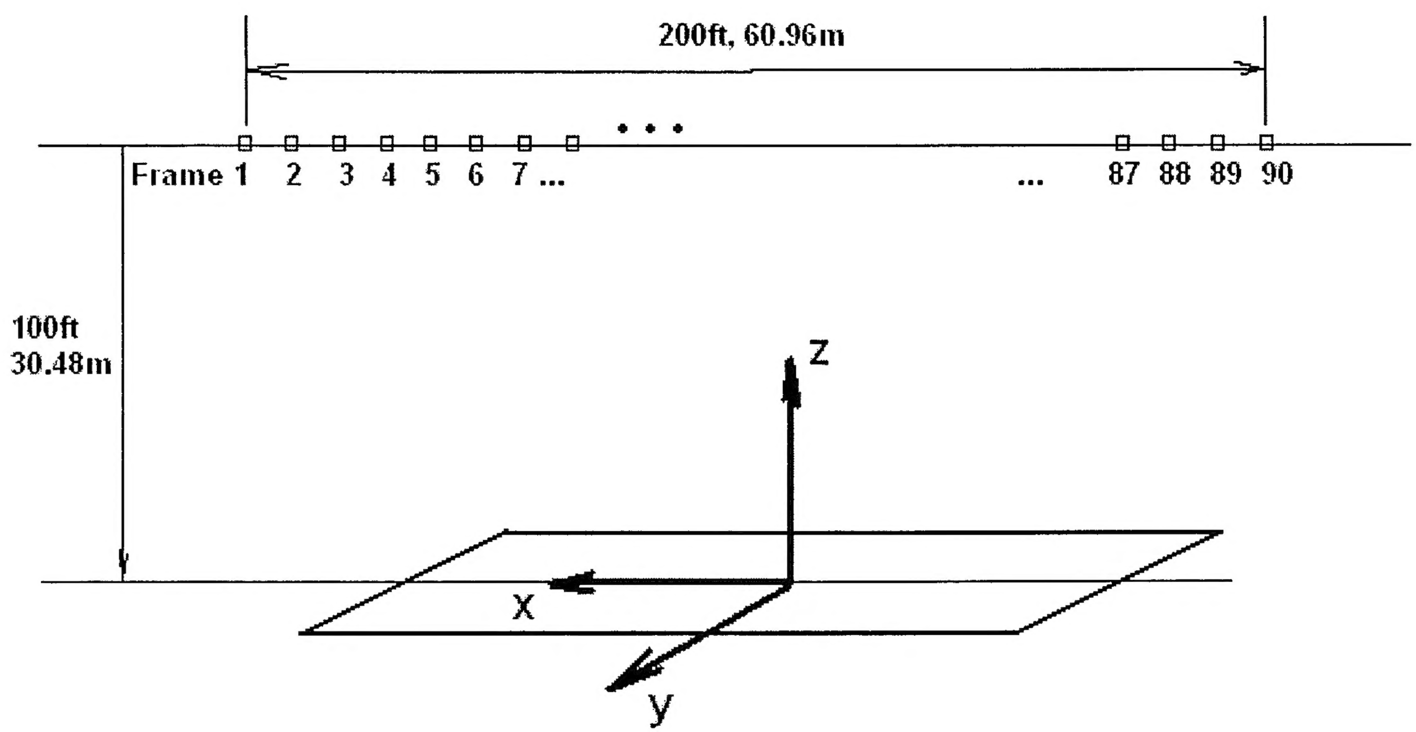
Overview of the Compression Engine: JPEG2000☆



☆ D.S. Taubman and M.W. Marcellin, '*JPEG2000: Image Compression Fundamentals, Standards, and Practice*,' Kluwer Academic Publishers, 2002.

Sensor Geometry

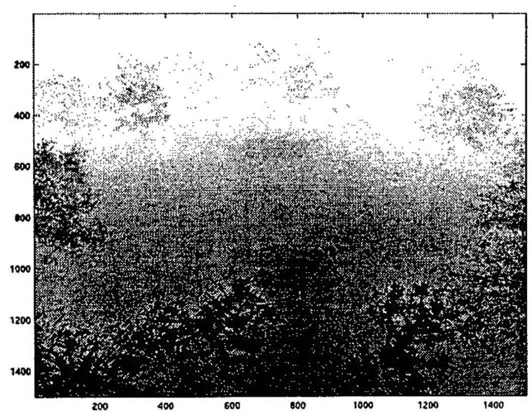
- Sensor collects range images from various positions/angles
- Each image measures a subset of all scene voxels
- World coordinate origin is located at image center/ground plane



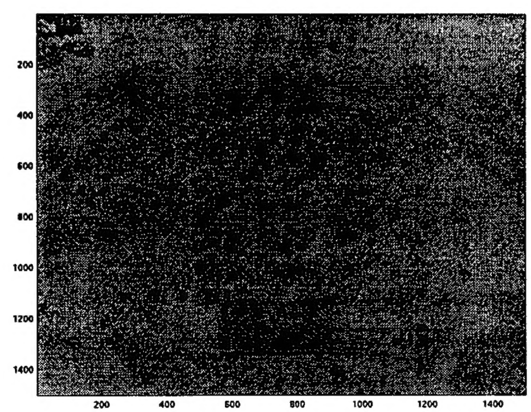
Frame-by-Frame Range Image Compression

- We begin with independent compression/decompression of simulated range imagery

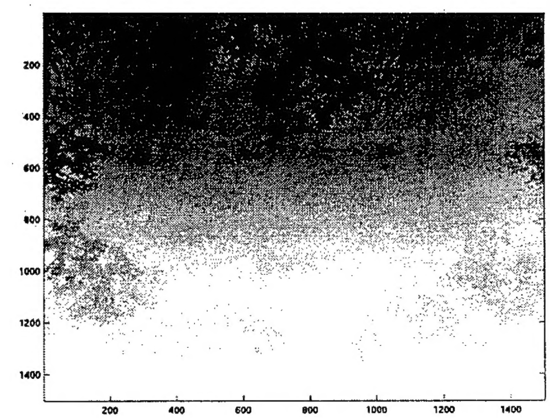
Three Range Images



Sensor Location 1



Sensor Location 38

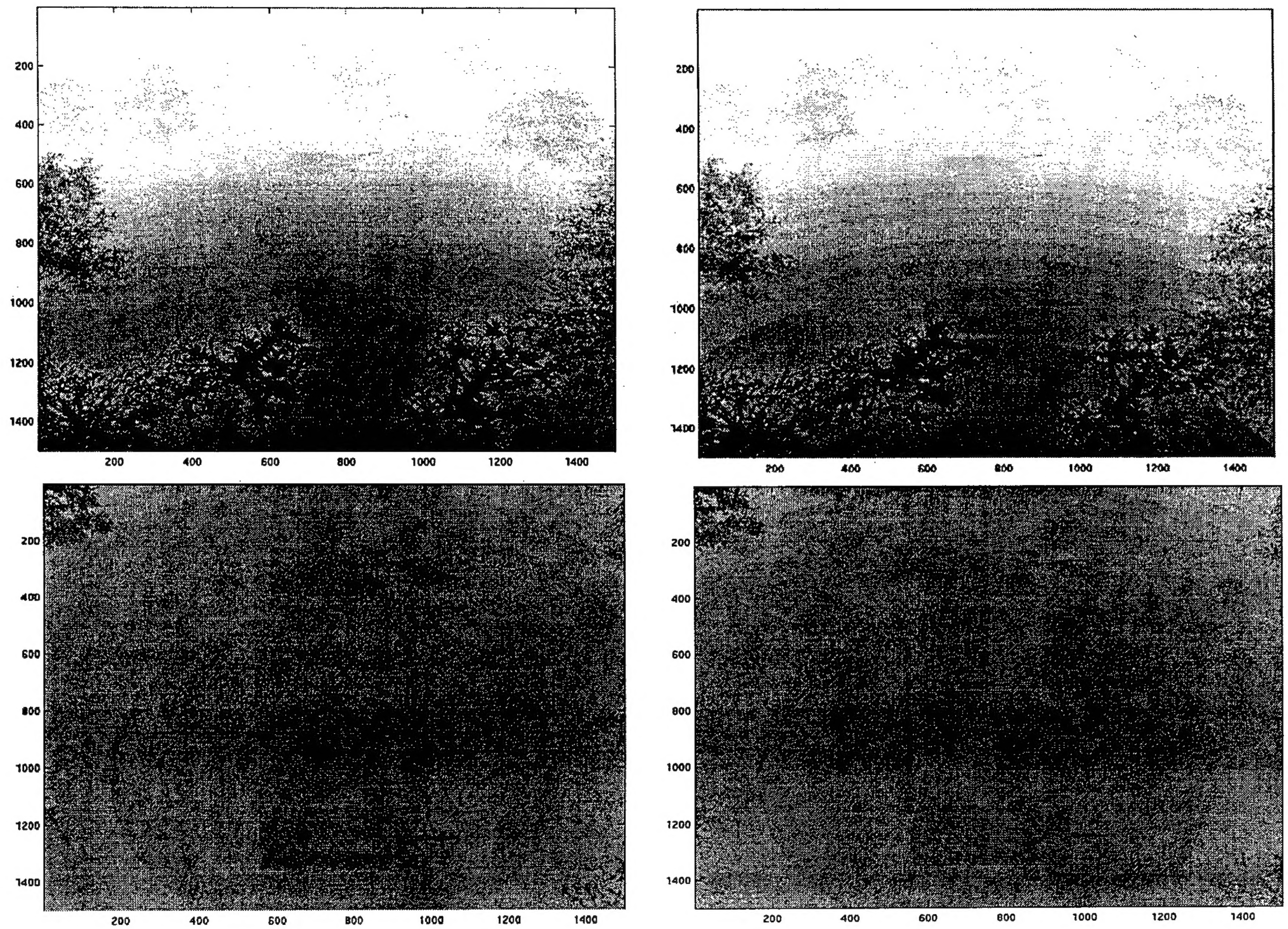


Sensor Location 90

Visual Results

1

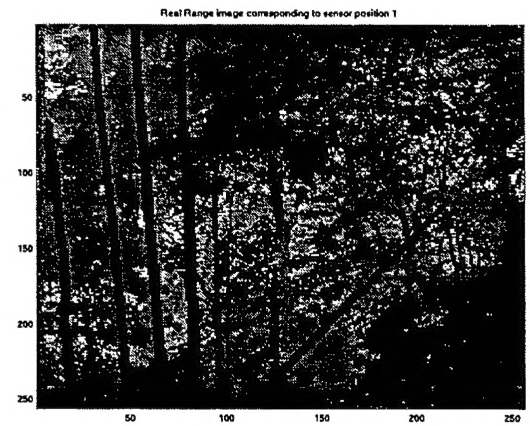
38



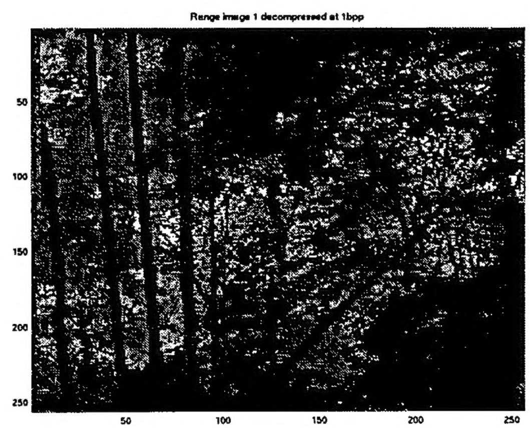
Raw Data

0.1 bpp

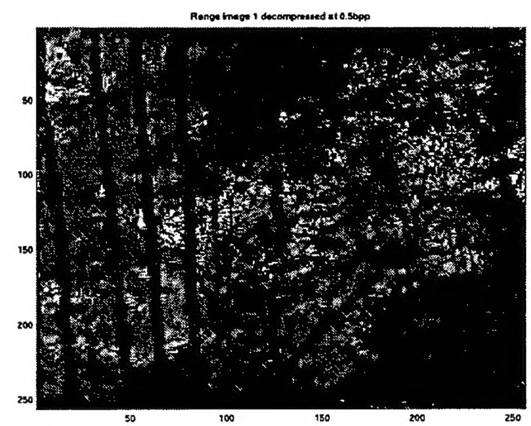
Experimental results: real data



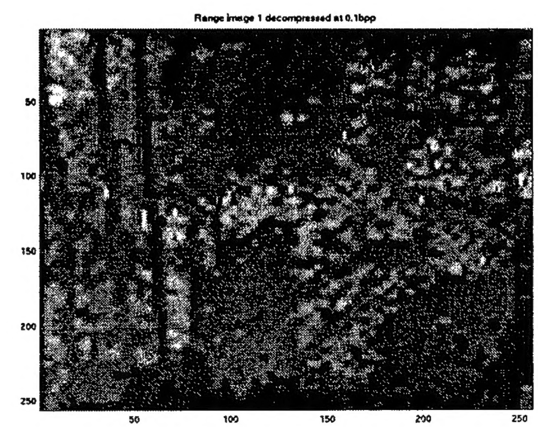
Sensor Location 1



Rate = 1.0bpp
MSE = 1.98 m

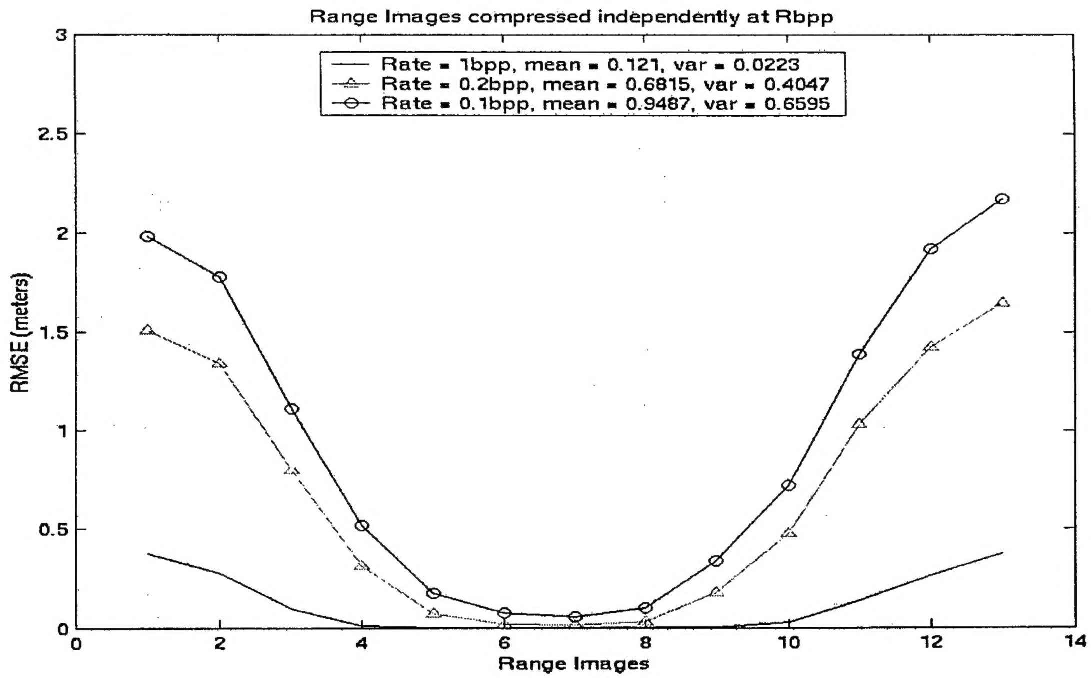


Rate = 0.5bpp
MSE = 3.01 m



Rate = 0.1bpp
MSE = 4.83 m

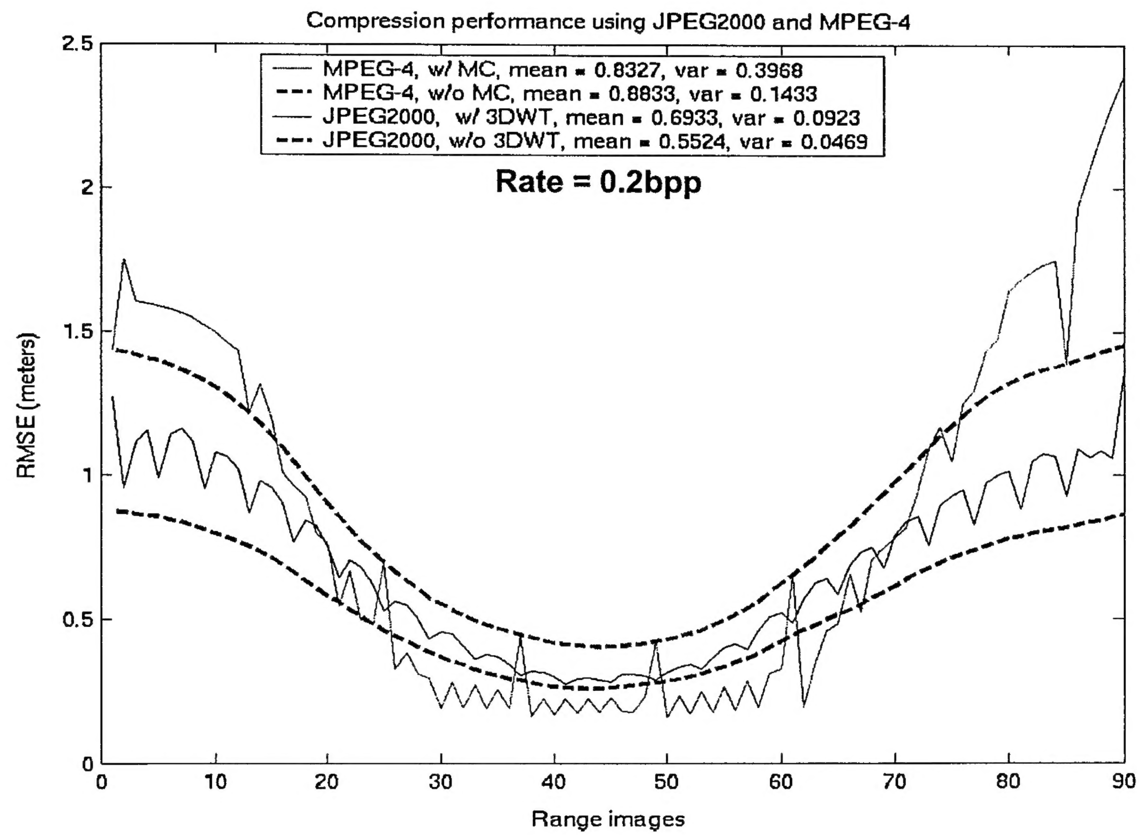
MSE Results



- Range images corresponding to nadir viewing are more easily compressed
- Four reasons:
  - Differing dynamic range
  - Differing levels of foliage
  - Differing ground sample distances
  - Linear trend

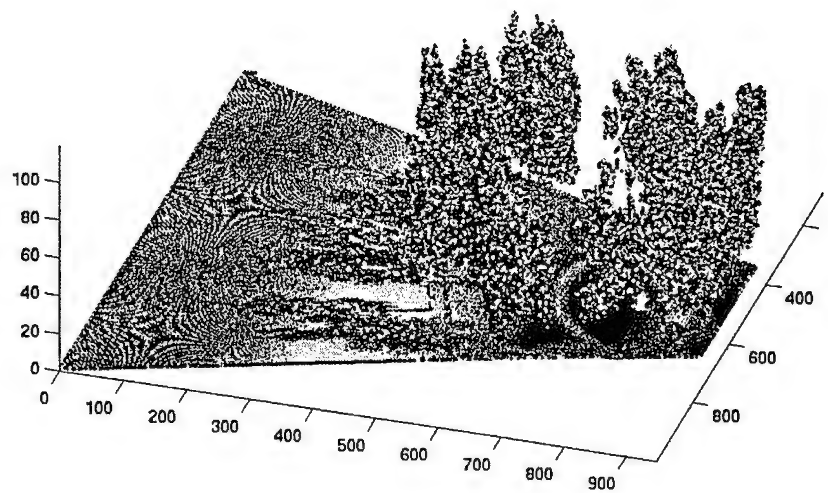
Interdependent Range Image Compression

- Treat range images as a video sequence and exploit temporal correlation using:
  - Motion Compensation (e.g., MPEG4)
  - Wavelet transform (e.g., JPEG2000 with a 3DWT)

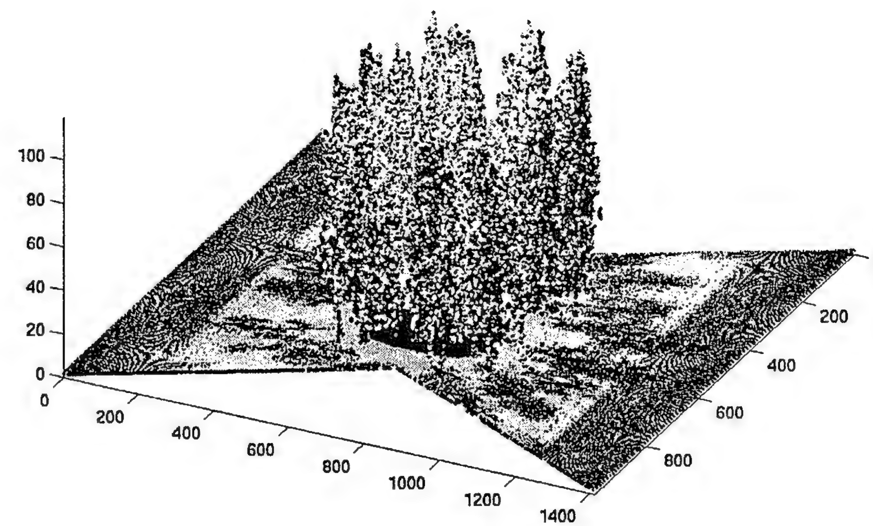


- The "temporal" correlation is hard to exploit … except near-nadir
- JPEG2000 does a good job allocating rate between frames

Volumetric Data Representation



Histogram Volume
using Sensor Data #1

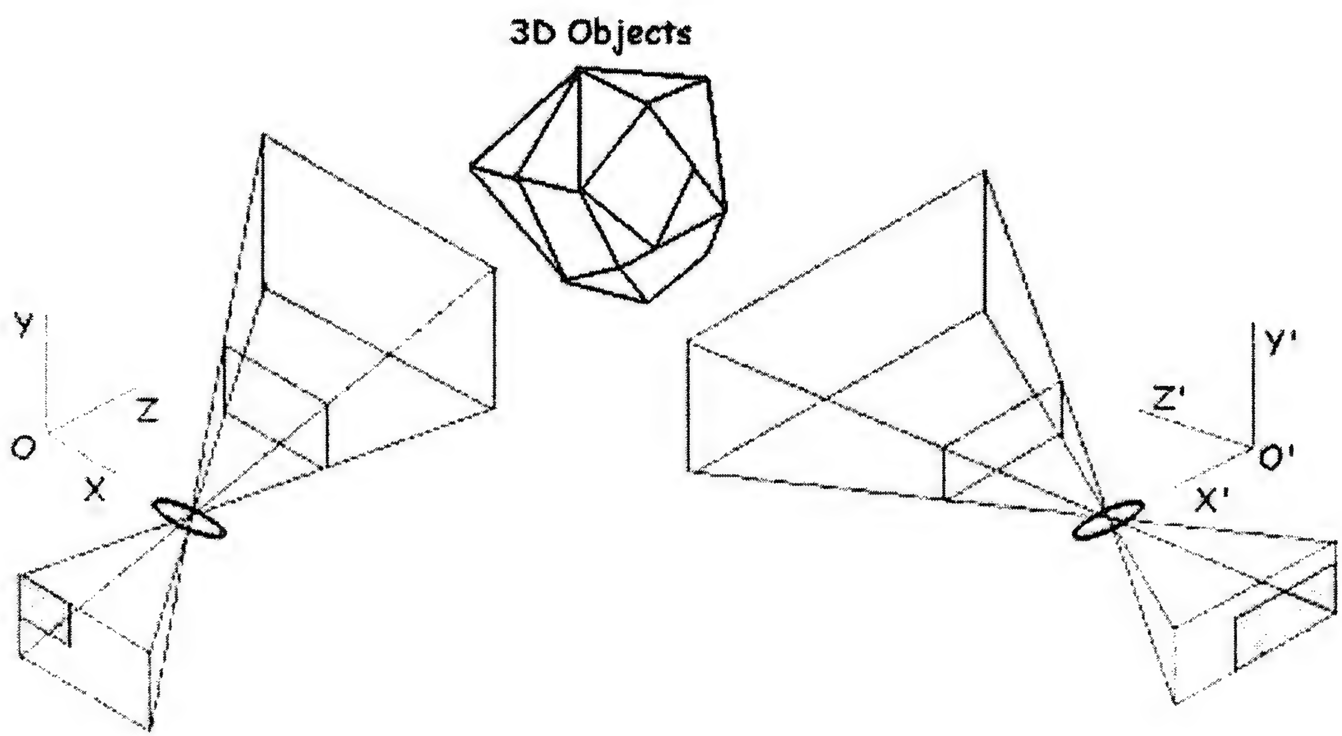


Histogram Volume
using all 90 Sensor Positions

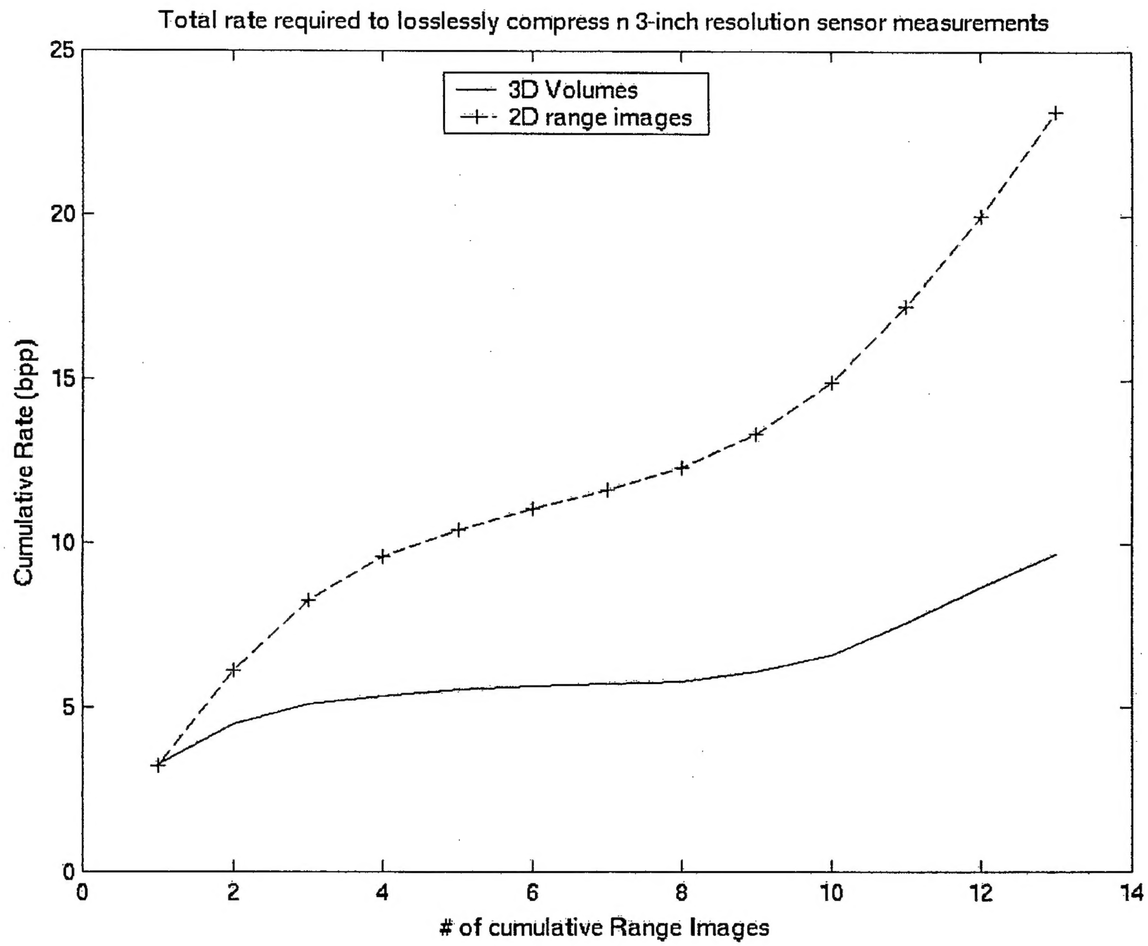
V(a,b,c) = # of returns the sensor registered in a cube centered around $(a*\Delta,b*\Delta,c*\Delta)$ and whose volume in space is Δ^3, where Δ is the resolution of the 3D volume.

Volumetric Data Compression

- Motivation:
  - Exploit redundancy between multiple views

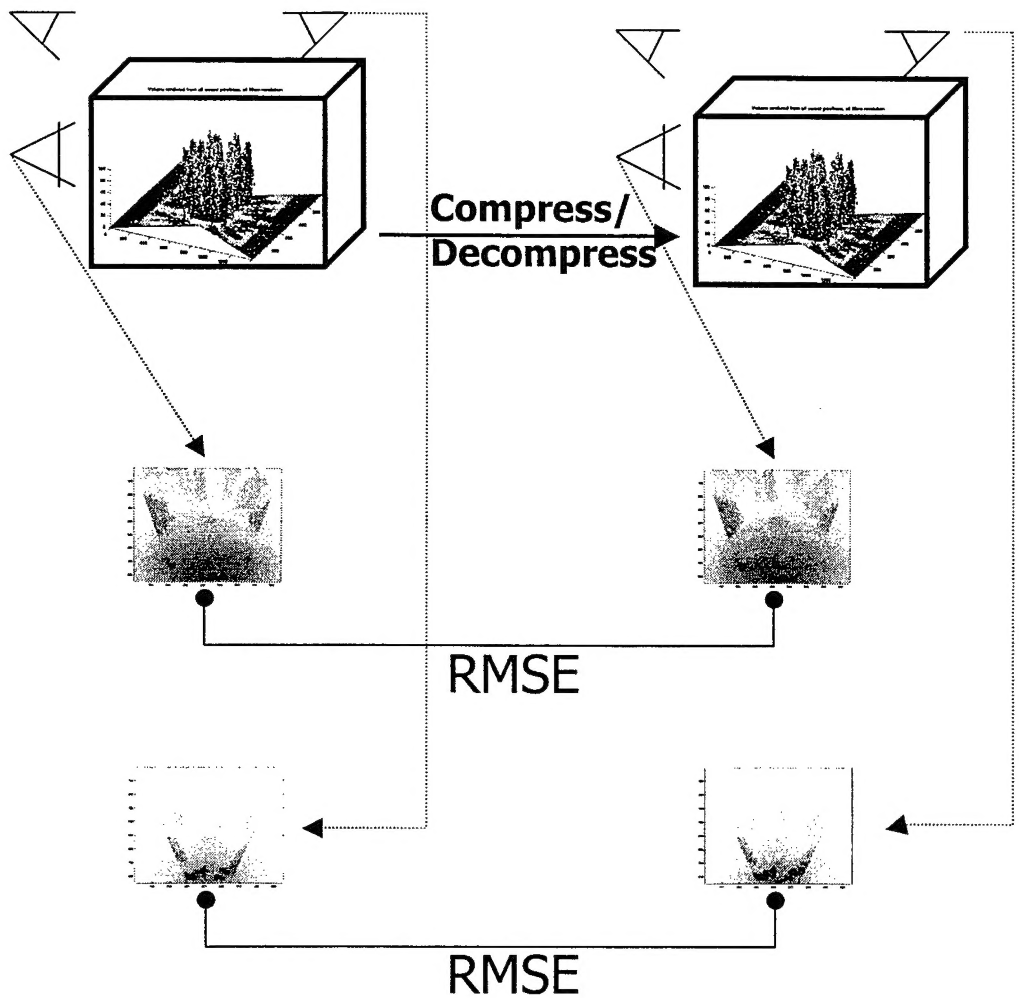


Lossless Compression: Results



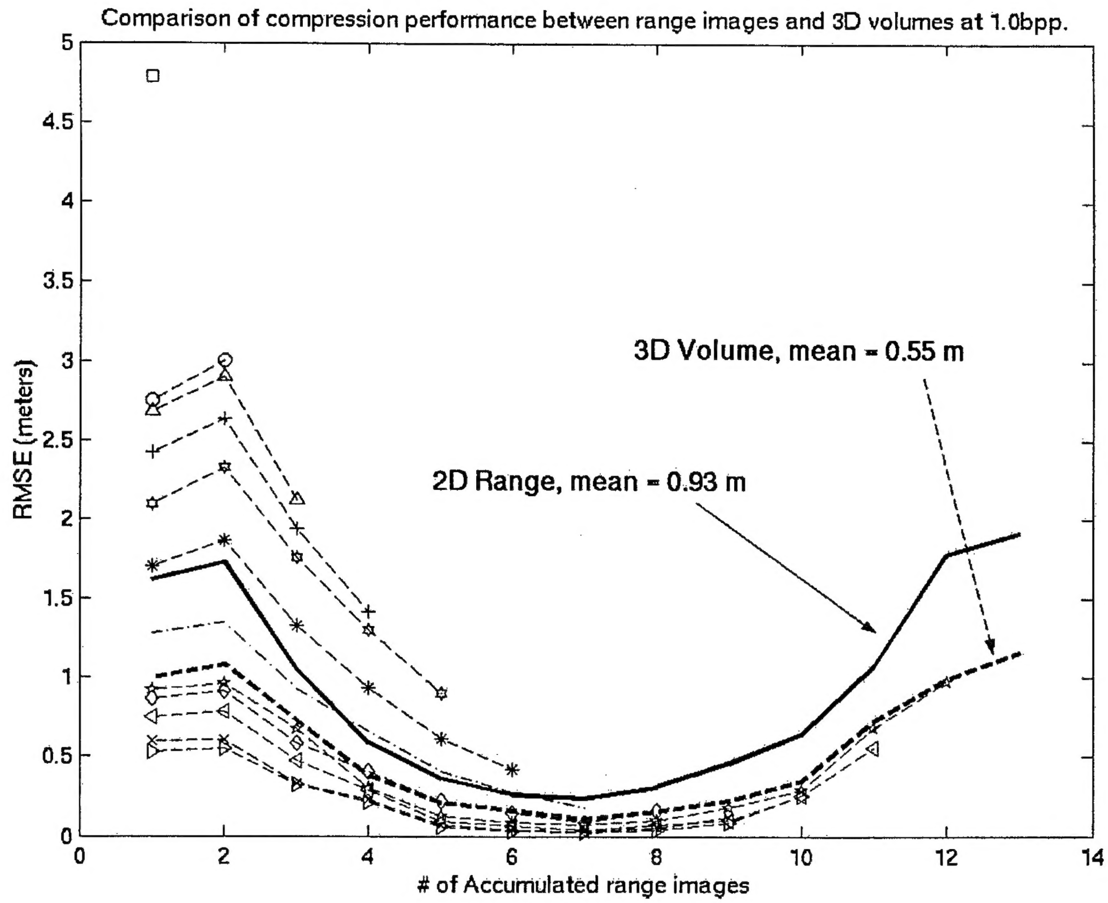
- Ultimately, compressing 3D Volumes yields a file size **60%** smaller compared to that obtained by independently compressing the same number of 2D range images.

Lossy Compression: Error Metric



- Compress volume such that the number of bytes used to send this volume is the same as the cumulative file size of the compressed range images that alternatively could have been sent, i.e. constant file size constraint.

Lossy Compression: Results



- For the same file size, the average RMSE for 3D decompressed Volumes converges to a value that is 40% less than the average RMSE for the corresponding decompressed range images.

Conclusions

- **Goal of proposed work**: Efficient compression of volumetric data generated by single-platform (mobile) range sensors.
- **General Approach**: Exploit correlation structure inherent in multiple views.
- For 2D range images, this correlation is hard to exploit using traditional compression techniques,
  - An algorithm that takes into consideration the changes in "perspective" between successive views is under development.
- The 3D volumetric representation yields significantly better compression performance compared to 2D,
  - Moreover, 3D volumes offer additional functionalities (e.g., collaborative/predictive compression techniques for distributed sensing, super-resolution, etc...),
  - Future efforts: use 3D context-modeling to *better* exploit the correlation in the 3D physical world.